

## Treatment of distal tibia fractures with intramedullary nail or plate: A meta-analysis

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### ABSTRACT

**Objectives:** To evaluate the outcome of intramedullary nail and plate fixation for the treatment of extra-articular fractures of the distal tibia and to determine whether there are sufficient objective data in the literature to compare the two methods.

**Methodology:** A comprehensive search of all relevant articles from Jan 1975 to Dec 2011 was conducted. Two reviewers evaluated each study to determine its suitability for inclusion and collected the data of interest. Meta-analytic pooling of group results across studies was performed for the two treatment methods.

**Results:** The systematic review identified 22 primary studies with 880 fractures including 15 groups of intramedullary nail and 15 groups of plate. For extra-articular distal tibia fractures, shorter healing time can be achieved by using the intramedullary nail, but the malformation rate was significantly higher than in the plate group. The average operating time in the intramedullary nail group was longer than in the plate group, but the difference was not statistically significant. No statistically significant difference was found when comparing the rates of infection, rotation, shortening, delayed union and nonunion. The reoperation rate was higher in the intramedullary nail group compared with the plate group, but the difference was also not statistically significant.

**Conclusions:** The functional and efficacy outcomes appear to be similar between the two treatment groups. Thus the patient's general condition and the surgeon's preference dictate the choice of surgical technique.

**KEYWORDS:** Meta-analysis, Fracture, Tibia, Intramedullary, Plate fixation.

Pak J Med Sci July - September 2012 Vol. 28 No. 4 580-585

### How to cite this article:

Tao Yu, Qianming Li, Hongmou Zhao, Jiang Xia, Ashwin Aubeeluck, Guangrong Yu. Treatment of distal tibia fractures with intramedullary nail or plate: A Meta-Analysis. Pak J Med Sci 2012;28(4):580-585

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- \* Received for Publication: March 23, 2012
- \* Revision Received: June 9, 2012
- \* Revision Accepted: June 18, 2012

### INTRODUCTION

Extra-articular fractures of the distal tibia are common. Such fractures are often difficult to treat, since they are close to the ankle joint and usually associated with severe comminution and soft tissue injury. They should be treated with internal fixation because conservative treatment and external fixation are likely to cause loss of reduction and malunion, or pin tract infection with external fixation.<sup>1</sup> But which is the best operative method of internal fixation has not been conclusive. Plate fixation and intramedullary nail are two well-accepted and effective methods. Plate fixation for distal tibial fractures can achieve anatomical reduction, but may result in delayed union non-union or soft-tissue complications.

Intramedullary nail can reduce the damage to soft tissue, but may result in malunion, breakage of the nail and locking screws and risk of propagation of the fracture into the ankle joint. Both techniques provide reliable fixation but both are associated with specific complications. There is little information regarding the functional recovery following either procedure. Over the last 20 years, clinicians have made many attempts to treat this fracture with intramedullary nail and plate fixation and there have been numerous articles about this. To clarify the advantages and disadvantages of each method, a meta-analysis was performed for the two treatment methods through comprehensive search, review, extracting and analyzing data of all relevant articles. We hope that the better method will be found out between the two through the analysis. With this attempted meta-analysis, the advantages and disadvantages of the two methods were summed up respectively. We believe that it will be helpful to make wiser clinical decisions to benefit the patients ultimately.

## METHODOLOGY

Meta-analysis is a statistical technique for combining the findings from independent studies. Before starting the systematic search, the research question, inclusion and exclusion criteria, the treatments of interest and the outcomes of interest were defined. Every step of this research was completed by two authors separately and independently.

**Inclusion Criteria:** 1. Literature written in the English language. 2. The articles that reported extra-articular fractures of distal tibia. 3. The literature involving type 43A or 43B1 or 43C1 or 42A-C by AO/OTA classification. 4. Age of patients  $\geq 19$  years old. 5. Average time of following up  $\geq 6$  months. 6. Number of cases  $\geq 9$ .

**Exclusion Criteria:** 1. Extra-articular fractures of the distal tibia were treated with external fixator or non-surgical treatment. 2. Stress fractures, pathologic fractures or childhood fractures. 3. Mixed reports of intra-articular and extra-articular fractures. 4. Biomechanical models, animal studies, review articles, isolated case reports, technique papers. 5. Complex intra-articular fractures.

**Treatment of Interest:** The treatments of interest included intramedullary nailing and plate fixation with or without bone grafting. It means that all the studies about extra-articular fractures of the distal tibia treated with intramedullary nailing and plate fixation were included regardless of with or

without bone grafting. And it was found that the separate data was too difficult to extract.

**Outcomes of Interest:** The outcomes of interest included operating time, fracture healing time, complications such as infection, malunion, angulation, rotation, shortening, delayed healing, non-healing, reoperation. Infection was defined as clinical evidence of superficial infection, deep infection and osteomyelitis. Several times or types of infection that occurred in the same patient were considered as one case of infection. Malunion was defined as shortening of more than 1 cm, axial angulation of more than  $5^\circ$  and angular rotation of more than  $10^\circ$ . Delayed healing was defined as healing time of 6~9 months and more than 9 months for non-healing. Reoperation includes the dynamization of the intramedullary nail, bone grafting for delayed healing, debridement for postoperative infection, replacement of internal fixation and fixation removal due to complications.

**Search Technique:** A comprehensive search of Medline and Embase using the key words "distal", "tibia" and "fracture" revealed over 1500 articles. After limiting the search to clinical trials in English and excluding pediatric age groups as well as biomechanical and animal studies, 621 articles were identified in the period from January 1975 to Dec 2011. Then the abstracts or original articles were reviewed to determine whether they could be included. Finally, 22 articles<sup>2-23</sup> met the inclusion but not the exclusion criteria (Table-I).

**Statistical Analysis:** All included patients were divided into the intramedullary nail group and the plate fixation group. Meta-analytic pooling of group results across studies was performed for the two treatment methods. There were two statistical methods which were direct sum and meta-weighted. 95% confidence interval (95% CI) was calculated in the indicators of meta-weighted method. The  $\chi^2$ -test was used to test the difference ( $P < 0.05$  indicated statistically significant difference). All statistical analysis was performed by SAS 9.1.3 (SAS Institute Inc., Cary, NC, USA) and STATA 7.0 (StataCorp LP, College Station, TX, USA).

## RESULTS

The systematic review identified 22 primary studies with 880 fractures (Table-II) including 15 groups of intramedullary nail and 15 groups of plate. The average operating time in the intramedullary nail group was longer than in the plate group, but the difference was not statistically significant. The average healing time in the

Table-I: Selected Articles.

| Article              | Study Design    | Fixation Type | Ture N        |
|----------------------|-----------------|---------------|---------------|
| Bostman O,et al*     | Case Series     | IN            | 32            |
| Egol KA,et al*       | Retrospective C | IN            | 25 and 47**   |
| Ehlinger M,et al*    | Case Series     | IN            | 42            |
| Guo JJ,et al*        | Prospective C   | IN vs PF      | 44 and 41     |
| Im GI,et al*         | Prospective C   | IN vs PF      | 34 and 30     |
| Janssen KW,et al*    | Case Control    | IN vs PF      | 12 and 12     |
| Krishan A,et al*     | Case Series     | IN            | 25            |
| Nonnemann HC,et al*  | Case Series     | IN            | 64            |
| Obremskey WT,et al*  | Retrospective C | IN            | 38 and 18***  |
| Tyllianakis M,et al* | Case Series     | IN            | 73            |
| Vallier HA,et al*    | Retrospective C | IN vs PF      | 76 and 37     |
| Wu CC,et al*         | Case Series     | IN            | 28            |
| Yang SW,et al*       | Retrospective C | IN vs PF      | 13 and 14     |
| Borg T,et al*        | Case Series     | PF            | 21            |
| Manninen MJ,et al*   | Case Series     | PF            | 20            |
| Ahmad MA,et al*      | Case Series     | PF            | 17            |
| Ozkaya U,et al*      | Retrospective C | PF            | 21 and 22**** |
| Redfern DJ,et al*    | Case Series     | PF            | 20            |
| Shantharam SS,et al* | Case Series     | PF            | 8             |
| Sheerin DV,et al*    | Case Series     | PF            | 15            |
| Sohn OJ,et al*       | Case Series     | PF            | 10            |
| Oh CW,et al*         | Case Series     | PF            | 21            |

\*Studies used in statistical analysis; \*\*Two fixation types were considered as two studies (25 with fibulas fixed and 37 not); \*\*\*Operations performed by different doctors were considered as two studies (38 by orthopedic surgeon and 18 by emergency doctor); \*\*\*\*Fractures fixed by two types of plate were considered as two studies (21 by ordinary plate and 22 by locking plate); True N, meaning that only those patients who were followed up and/or met exact inclusion/exclusion criteria out of total patient population.

Retrospective C=Retrospective Comparative Study; Prospective C=Prospective Comparative Study; IN=Intramedullary Nail; PF=Plate Fixation.

intramedullary nail group was statistically shorter than the plate group (Table-III). No statistically significant difference was found when comparing the rates of infection, rotation, shortening, delayed union and nonunion. The reoperation rate was higher in the intramedullary nail group compared with the plate group, but the difference was also not statistically significant. The malunion and angulation rates were statistically higher in the plate group (Table-IV).

## DISCUSSION

The treatment of extra-articular fractures of the distal tibia is controversial. Good reduction and strong fixation can be achieved with plating, but this technique tends to disrupt the periosteal blood supply and increases the risk of infection, delayed union and nonunion.<sup>5-7,12,14</sup> It was reported that the incidence of infection was 23.3% including superficial infection in 6 cases and deep infection in 1, out of 30 cases of plating, with average follow-up

time of 24 months.<sup>6</sup> A straight incision was made over the anterior border of distal tibia and anatomic plate and screws were used in this study. The plate was applied, which covers the anterior aspect of distal tibia and twisted upward to fit the lateral surface of the tibial shaft. The bias of outcomes may exist because of the limited number of cases in this study. And because of the limitations of each study, a meta-analysis is needed. The weighted average incidence of infection in plate group is 9.2% (95%CI: 4.7% - 13.7%) in our study.

Ahmad et al used plating in 17 patients and reported a success rate of only 76.4%. Plating was preferred to nailing in the past because of restrictions in intramedullary nail technology, but with progress in that field, intramedullary nailing is being performed more and more often. Advocates of intramedullary nailing state that this technique can protect blood supply reduce soft tissue destruction and lower the incidence of postoperative infection and delayed healing.<sup>3-8,10-14,17</sup>

Table-II: Information of the patients.

|                       | Intramedullary Nail Group |                | Plate Group |                |
|-----------------------|---------------------------|----------------|-------------|----------------|
|                       | Studies                   | Results/Case N | Studies     | Results/Case N |
| Case N                | 15                        | 571            | 15          | 309            |
| Male/Patients         | 12                        | 312/463*       | 12          | 185/274**      |
| Average age(year)     | 15                        | 39.4/571       | 13          | 43.7/286***    |
| Follow-up time(month) | 15                        | 21.1/571       | 15          | 22.9/309       |
| Evaluation Scale      | 6                         | /              | 10          | /              |
| OMA                   | 3                         | 85.7/89        | 3           | 87.6/65        |
| AOFAS                 | 1                         | 86.1/44        | 5           | 83.9/116       |
| KSRS                  | 1                         | 139/12         | 1           | 146/12         |
| IOWA                  | /                         | /              | 1           | 84.5/10        |

\*there was no gender information in three studies in the Intramedullary Nail Group.

\*\* there was no gender information in three studies in the plate Group.

\*\*\*there was no age information in two studies in the plate group.

OMA=Olerud and Molander ankle scores, which was developed by C. Olerud (Department of Orthopaedic Surgery, University Hospital, Uppsala, Sweden) and H. Molander (Department of Orthopaedic Surgery, County Hospital, Falun, Sweden) to provide a scoring system for evaluating symptoms after ankle fractures in 1984.

AOFAS = American Orthopaedic Foot & Ankle Society, here means Clinical Rating System for the ankle-hindfoot developed by AOFAS in 1994.

KSRS=Knee Society Rating System, which was developed by The Knee Society of the USA to provide an evaluation form of the knee in 1989.

IOWA is a state of the USA. IOWA ankle rating system was developed by the Department of Orthopaedic Surgery, University of Iowa Hospital and Clinics to provide an evaluation form of the ankle in 1989.

However the intramedullary nail does not solve the problem of line of force. It was associated with more malalignment versus plating,<sup>24</sup> because of that it is difficult to achieve and maintain a good reduction with intramedullary nail.<sup>25</sup> In 6 out of 25 patients axial angulations of over 5 degrees were reported, which represents an angulation rate of 24%.<sup>8</sup> Intramedullary nails were also used in the treatment of extra-articular fractures of the distal tibia in 42 cases including 14 cases with axial angulations over 5° and the angular deformity rate reached 33.3%.<sup>4</sup> However, it was revealed that there was no significant difference of malunion rate between plate and nail in some studies.<sup>26,27</sup> But those opinions were mainly based on personal experience and small samples. The results of the research differed greatly and it is not easy to determine the superiority of each treatment from those various data. As such we collected previous data for analysis in order to provide more conclusive evidence-based results.

According to our statistical analysis, the average operating time was longer in intramedullary nail group than the plate group. The shape of the tibial marrow cavity is like an hourglass, that is, thick at both ends and thin at the middle so that the bone can be firmly affixed by an intramedullary nail only in the middle part of the bone. Therefore there are different surgical techniques involved depending on whether one is dealing with midshaft or distal

tibial fractures. In cases of midshaft fractures, the distal fragment reduces itself when the intramedullary nail is inserted, but this does not happen with fractures of the distal tibia, which require an additional reduction step. But because of experience of the surgeon and other individual factors, the difference in operating time between the two methods was not statistically significant ( $P=0.143$ ). Intramedullary nailing was recommended by many authors mainly because plate fixation was thought to increase the risk of infection.<sup>7,14</sup> According to the comparison of 571 cases treated with intramedullary nail and 309 treated with plate in this study, the observed rate of infection of intramedullary nail group (5.7%) was lower than the plate group (9.2%), but the difference was not statistically significant ( $P = 0.139$ ).

Table-III: Comparison of the operating time and healing time of the fracture.

|                           | Average operating time (minutes) | Average healing time of the fracture (weeks) |
|---------------------------|----------------------------------|----------------------------------------------|
| Intramedullary Nail Group | 91.9/194                         | 18.1/435                                     |
| Plate Group               | 82.3/167                         | 20.4/301                                     |
| P                         | 0.143                            | 0.000*                                       |

\* $P < 0.05$ , the difference is statistically significant.

Table-IV: Comparison of the complications and reoperation.

|         | <i>Infection</i> | <i>Malunion</i> | <i>Angulation</i> | <i>Rotation</i> | <i>Shortening</i> | <i>Delayed union</i> | <i>Nonunion</i> | <i>Reoperation</i> |
|---------|------------------|-----------------|-------------------|-----------------|-------------------|----------------------|-----------------|--------------------|
| ING     | 30/571           | 72/571          | 68/571            | 4/499           | 0/499             | 29/571               | 19/571          | 79/571             |
| PG      | 30/309           | 16/309          | 10/309            | 5/309           | 1/309             | 15/309               | 9/309           | 24/309             |
| P 0.139 | 0.043*           | 0.009*          | 0.961             | 0.379           | 0.576             | 0.897                | 0.257           |                    |

ING= Intramedullary Nail Group, PG= Plate Group.

\*P <0.05, the difference is statistically significant.

There are different blood supplies inside and outside of the tibia. The periosteal blood vessels originate from anterior and posterior vessels of the tibia, nourishing one fifth to one third of the lateral cortical bone. The remaining bone cortex and endosteum are supplied by the metaphysis vessels and nutrient vessels.<sup>28</sup> Indeed, the reaming process results in the destruction of all vessels in the medullary canal. But after reaming and implantation of a medullary nail, the vessels grow into the gaps between nail and bone and then gain access to the widened Haversian canals. At the same time, periosteal vessels grow into the cortical bone. The extent of revascularization can vary in one cross-section.<sup>29</sup> In fact, the intramedullary nail does not affect the blood supply at the fracture area, while the plate does. In our study, the average healing time was shorter in the intramedullary nail group than in the plate group and the difference was statistically significant ( $P = 0.000$ ). Prognostic differences also existed between the two methods. Observed malunion rate was 14.7% in the intramedullary group, higher than the plate group (5.5%) and there was a statistically significant difference ( $P = 0.043$ ). Malunions in the intramedullary nail group were mainly angular deformities with a weighted rate of 12.8% compared to 3.1% in the plate group, this difference proving to be statistically significant ( $P = 0.009$ ). Malunion was defined as shortening of more than 1 cm (shortening), axial angulation of more than  $5^\circ$  (angulation) and angular rotation of more than  $10^\circ$  (rotation). The differences of rotation and shortening deformity were not statistically significant. Intramedullary nail is not good at maintaining rigid fixation and alignment. As mentioned earlier, the tibial marrow cavity cannot adapt to the intramedullary nail because of its hourglass-shaped structure so that anti-torsion and anti-angulation ability was greatly reduced.

There was no statistically significant difference in delayed union rate and nonunion rate between the intramedullary nail group and plate group. The reoperation rate was higher in the intramedullary nail group than the plate group, but the difference

was not statistically significant ( $P = 0.257$ ). Other surgery-related complications and postoperative functional scale scores weren't pooled and analyzed because the reports were relatively scattered and there was no uniform method of outcome assessment.

According to the results of this study, the fracture can heal a little faster with the application of intramedullary nail so that functional exercises can be started earlier whereas the risk of malunion is obvious lower in the plate group. In addition, the infection incidence is not higher with the plate fixation as we thought before. Therefore, to some extent overall the plate is superior to the intramedullary nail.

## CONCLUSION

In summary, with ideal reduction and maintenance, plate fixation is a recommended method for extra-articular fractures of distal tibia unless there is severe injury of the soft tissue. But the functional and efficacy outcomes appear to be similar between the two treatment groups. Therefore, the choice of surgical procedure should be based on the individual condition of the patient and the surgeon's preference ultimately.

## REFERENCES

1. Demiralp B, Atesalp AS, Bozkurt M, Bek D, Tasatan E, Ozturk C, et al. Spiral and oblique fractures of distal one-third of tibia-fibula: treatment results with circular external fixator. *Ann Acad Med Singapore* 2007;36(4):267-271.
2. Bostman O, Vainionpaa S, Saikku K. Infra-isthmal longitudinal fractures of the tibial diaphysis: results of treatment using closed intramedullary compression nailing. *J Trauma* 1984;24(11):964-969.
3. Egol KA, Weisz R, Hiebert R, Tejwani NC, Koval KJ, Sanders RW. Does fibular plating improve alignment after intramedullary nailing of distal metaphyseal tibia fractures. *J Orthop Trauma* 2006;20(2):94-103.
4. Ehlinger M, Adam P, Gabrion A, Jeunet L, Dujardin F, Asencio G. Distal quarter leg fractures fixation: The intramedullary nailing alone option. *Orthop Traumatol Surg Res* 2010;96(6):674-682.

5. Guo JJ, Tang N, Yang HL, Tang TS. A prospective, randomised trial comparing closed intramedullary nailing with percutaneous plating in the treatment of distal metaphyseal fractures of the tibia. *J Bone Joint Surg Br* 2010;92(7):984-988.
6. Im GI, Tae SK. Distal metaphyseal fractures of tibia: a prospective randomized trial of closed reduction and intramedullary nail versus open reduction and plate and screws fixation. *J Trauma* 2005;59(5):1219-1223.
7. Janssen KW, Biert J, Van KA. Treatment of distal tibial fractures: plate versus nail: a retrospective outcome analysis of matched pairs of patients. *Int Orthop* 2007;31(5):709-714.
8. Krishan A, Peshin C, Singh D. Intramedullary nailing and plate osteosynthesis for fractures of the distal metaphyseal tibia and fibula. *J Orthop Surg (Hong Kong)* 2009;17(3):317-320.
9. Nonnemann HC, Blariza G. The application of the Maatz-spreading-nail in operative treatment of distal tibial fractures. *J Trauma* 1976;16(8):604-609.
10. Obremskey WT, Medina M. Comparison of intramedullary nailing of distal third tibial shaft fractures: before and after traumatologists. *Orthopedics* 2004;27(11):1180-1184.
11. Tyllianakis M, Megas P, Giannikas D, Lambiris E. Interlocking intramedullary nailing in distal tibial fractures. *Orthopedics* 2000;23(8):805-808.
12. Vallier HA, Le TT, Bedi A. Radiographic and clinical comparisons of distal tibia shaft fractures (4 to 11 cm proximal to the plafond): plating versus intramedullary nailing. *J Orthop Trauma* 2008;22(5):307-311.
13. Wu CC, Shih CH. Complicated open fractures of the distal tibia treated by secondary interlocking nailing. *J Trauma* 1993;34(6):792-796.
14. Yang SW, Tzeng HM, Chou YJ, Teng HP, Liu HH, Wong CY. Treatment of distal tibial metaphyseal fractures: Plating versus shortened intramedullary nailing. *Injury* 2006;37(6):531-535.
15. Borg T, Larsson S, Lindsjo U. Percutaneous plating of distal tibial fractures. Preliminary results in 21 patients. *Injury* 2004;35(6):608-614.
16. Manninen MJ, Lindahl J, Kankare J, Hirvensalo E. Lateral approach for fixation of the fractures of the distal tibia. Outcome of 20 patients. Technical note. *Arch Orthop Trauma Surg* 2007;127(5):349-353.
17. Ahmad MA, Sivaraman A, Zia A, Rai A, Patel AD. Percutaneous Locking Plates for Fractures of the Distal Tibia: Our Experience and a Review of the Literature. *J Trauma Acute Care Surg* 2012;72(2), E81-87.
18. Ozkaya U, Parmaksizoglu AS, Gul M, Sokucu S, Kabukcuoglu Y. Minimally invasive treatment of distal tibial fractures with locking and non-locking plates. *Foot Ankle Int* 2009;30(12):1161-1167.
19. Redfern DJ, Syed SU, Davies SJ. Fractures of the distal tibia: minimally invasive plate osteosynthesis. *Injury* 2004;35(6):615-620.
20. Shantharam SS, Naeni F, Wilson EP. Single-incision technique for internal fixation of distal tibia and fibula fractures. *Orthopedics* 2000;23(5):429-431.
21. Sheerin DV, Turen CH, Nascone JW. Reconstruction of distal tibia fractures using a posterolateral approach and a blade plate. *J Orthop Trauma* 2006;20(4):247-252.
22. Sohn OJ, Kang DH. Staged protocol in treatment of open distal tibia fracture: using lateral MIPO. *Clin Orthop Surg* 2011;3(1):69-76.
23. Oh CW, Kyung HS, Park IH, Kim PT, Ihn JC. Distal tibia metaphyseal fractures treated by percutaneous plate osteosynthesis. *Clin Orthop Relat Res* 2003;408:286-291.
24. Vallier HA, Cureton BA, Patterson BM. Randomized, prospective comparison of plate versus intramedullary nail fixation for distal tibia shaft fractures. *J Orthop Trauma* 2011;25(12):736-741.
25. S.D.S. Newman, C.P.C. Mauffrey, S. Krikler. Distal metadiaphyseal tibial fractures. *Injury* 2011;42(10):975-984.
26. Vallier HA, Cureton BA, Patterson BM. Factors influencing functional outcomes after distal tibia shaft fractures. *J Orthop Trauma* 2012;26(3):178-183.
27. Li Y, Liu L, Tang X, Pei F, Wang G, Fang Y, et al. comparison of low, multidirectional locked nailing and plating in the treatment of distal metadiaphyseal fractures. *Int Orthop* 2012;Feb 7. [Epub ahead of print]
28. Borrelli J Jr, Prickett W, Song E, Becker D, Ricci W. Extraosseous blood supply of the tibia and the effects of different plating techniques: a human cadaveric study. *J Orthop Trauma* 2002;16(10):691-695.
29. Kessler SB, Hallfeldt KK, Perren SM, Schweiberer L. The effects of reaming and intramedullary nailing on fracture healing. *Clin Orthop Relat Res* 1986;(212):18-25.